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Microprocessor Control of Rotogravure Airflows

Acurex Corp., Mountain View, CA

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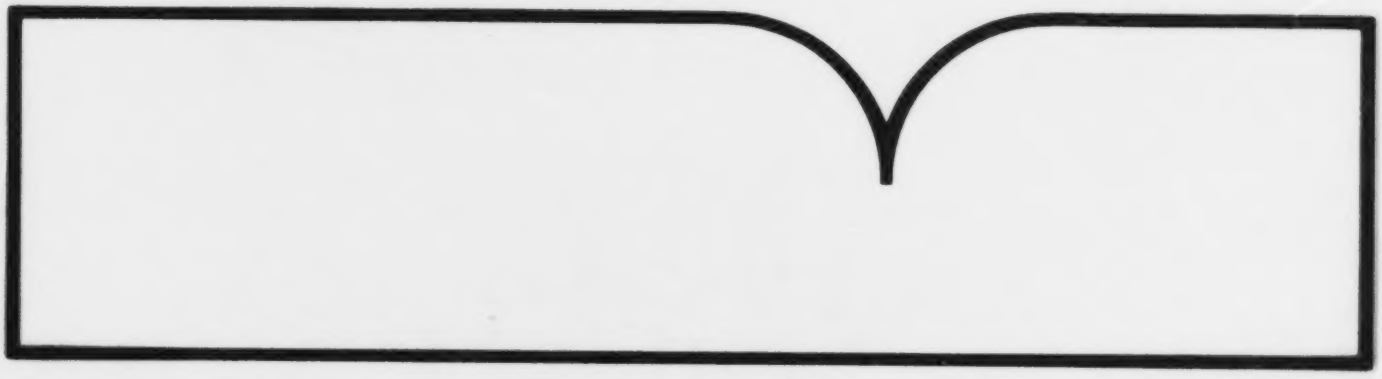

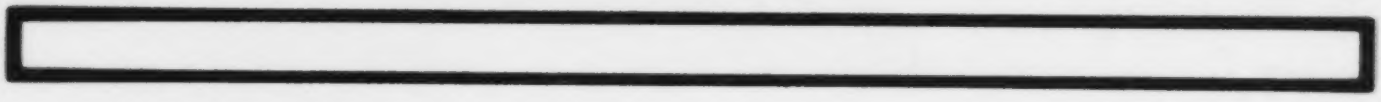

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MICROPROCESSOR CONTROL OF ROTOGRAVURE AIRFLOWS

by

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16. ABSTRACT The report discusses the technical and economic viability of using microprocessor-based control technology to collect volatile organic compound (VOC) emissions from a paper coating operation. The microprocessor-based control system monitors and controls both the airflow rate and vapor concentration level within the printing press dryers. It incinerates the VOC emissions in the plant's existing steam boiler and also saves energy by reducing the amount of dryer and room air that must be heated. The general concept, performance levels, and economic parameters of the evaluated VOC control system demonstrate the potential advantages of the technology for a wide range of applications. Three methods were considered to collect and destroy VOC emissions for the rotagravure operation: solvent recovery, thermal destruction in a dedicated incinerator, and thermal destruction in an existing onsite boiler. For the evaluated system, the use of the existing boiler is the best option even though equipment had to be added to collect, transport, and control the rotagravure airflows. The microprocessor and sensors which are an integral part of the emission control system enable the system to safely reduce the flowrate of air through the presses: the sensors measure the air pressure and VOC concentration in the press dryer exhaust, and the microprocessor maintains proper flowrates.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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Volatility	Stationary Sources	13H
Paper Coating Processes	Rotogravure	
Automation	Volatile Organic Compounds (VOC)	09C 20D 14G 07D
Monitors	Microprocessing	07C 13A
Microelectronics		
Air Flow		
Emission		
Vapors		
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ABSTRACT

This report is submitted in fulfillment of Contract No. 68-02-3993/WA18. It discusses the technical and economic viability of using microprocessor-based control technology to collect volatile organic compound (VOC) emissions from a paper coating operation. The specific system evaluated is operating at the James River Corporation rotogravure printing facility in Kalamazoo, Michigan.

The microprocessor-based control system monitors and controls both airflow rate and vapor concentration level within the printing press dryers. This system enables incineration of the VOC emissions in the plant's existing steam boiler and also provides energy savings by reducing the amount of dryer and room air that must be heated. The general concept, performance levels, and economic parameters for the James River VOC control system demonstrate the potential advantages of the technology for a wide range of applications.

James River looked at three methods to collect and destroy VOC emissions for their rotogravure operation: solvent recovery, thermal destruction in a dedicated incinerator, and thermal destruction in an existing onsite boiler. For James River, the use of their existing boiler is the best option even though they were required to add equipment to collect, transport, and control the rotogravure airflows.

The microprocessor and sensors which are an integral part of the emission control system enable James River to safely reduce the flowrate of air through their presses. The sensors measure the air pressure and VOC concentration in the press dryer exhaust, and the microprocessor adjusts fan speeds to maintain proper flowrates.

Over a 3-day period, operating data were recorded to evaluate the flow systems performance. With the microprocessor in operation, James River expected to see flowrates of less than 30 percent of the flow prior to conversion. This expectation was confirmed by measurements taken during the test period. Despite the flowrate reduction, concentrations of VOCs remained safely below the lower flammability limit. These tests showed that a microprocessor system, appropriately tied to an incinerator or boiler, is an effective means of addressing federal and state VOC emission standards for the paper printing industry.

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SECTION 1

INTRODUCTION

1.1 PROJECT DESCRIPTION

This report discusses the technical and economic viability of using microprocessor-based control technology to collect volatile organic compound (VOC) emissions from a paper coating operation. The specific system evaluated is operating at the James River Corporation rotogravure printing facility in Kalamazoo, Michigan.

The microprocessor-based control system monitors and controls both airflow rate and vapor concentration level within the printing press dryers. The system in this study provides incineration of VOC emissions in the plant's existing steam boiler and also provides energy savings by reducing the amount of dryer and room air that must be heated. The general concept, performance levels, and economic parameters for the James River VOC control system demonstrate the potential advantages of microprocessor control technology for a wide range of applications.

VOC emissions react in the atmosphere to form ozone and other undesirable constituents of smog. As a result, James River Corporation initiated a program to control atmospheric emission of VOCs from their rotogravure printing operation. The objective in installing the control system was to collect and destroy the VOCs with the most cost-effective approach. Three potential methods of emissions control were evaluated:

- Solvent recovery
- Destruction in a dedicated incinerator
- Destruction in an existing onsite boiler

Evaluation of installation and operating costs for the three alternatives showed that the use of the existing boiler to incinerate VOCs was the best option for James River.

In order to have the collected air fit within the combustion air demand of the existing boiler, the collection system needed to operate at a lower overall flowrate. Lower flow has the added benefit of reducing the quantity of facility air that must be pulled into the collection system and heated in the dryers. However, at lower flowrates, the concentrations of VOC in the dryers can approach the lower flammability limit (LFL). Therefore, some method was required to monitor and control exhaust airflow rates and exhaust air %LFL level. A microprocessor-based system was selected by James River to satisfy the requirement. The microprocessor system automatically controls exhaust fan speeds to minimize airflow rates while maintaining safe VOC concentrations. The net reduction in flow allows the existing boiler to accept all rotogravure dryer flow.

The major elements of the VOC control and collection system at the James River plant are:

- A microprocessor based computer/controller
- A %LFL analyzer
- Variable speed motor drives
- Pressure transducers

- Diversion dampers
- Operator display panel

Several other modifications and subsystems were necessary to implement VOC destruction using the existing plant boiler. Air ductwork was installed between a transfer fan and the boiler forced draft fan. A new forced draft fan was installed because bearings on the existing fan would be damaged by the VOCs in the press exhaust air. Modifications were necessary to some press decks in order to provide better sealing, thereby allowing operation at reduced fan speeds.

As a part of the VOC control system, process parameters are monitored by permanent instrumentation. However, the existing system has no provisions for data storage. Therefore, process parameters of interest to this study were recorded during the test period by a temporary data acquisition system. The system consisted of a data interface unit and a personal computer. A floppy disk and thermal printer were also provided for hardcopy data output and storage.

1.2 RESULTS AND CONCLUSIONS

1.2.1 Performance of Microprocessor System

Table 1 shows the effect of the VOC control system on the flowrate of air through the four presses considered in this study and confirms that the system operated as expected during the data acquisition period. Measured airflow rates are very close to the expected values, which represent a 71 percent decrease in airflow when compared to the preconversion values. Despite the large decrease in airflow rates, %LFL remained well within acceptable values.

TABLE 1. VOC COLLECTION SYSTEM PERFORMANCE SUMMARY

	Prior to conversion	After conversion	
Press number	Exhaust flowrate scfm (l/s)	Expected exhaust flowrate scfm (l/s)	Measured exhaust flowrate scfm (l/s)
3047	20,000 (9,378)	6,000 (2,813)	6,105 (2,863)
3049	25,000 (11,723)	4,000 (1,876)	3,839 (1,800)
3051	7,000 (3,282)	4,200 (1,969)	4,245 (1,990)
3052	25,000 (11,723)	8,000 (3,751)	7,900 (3,704)
	77,000 (36,105)	22,200 (10,410)	22,089 (10,358)

1.2.2 Safety of Microprocessor Controlled Process

The control system incorporates several safety features and interlocks, including:

- LFL analyzer failure (flameout) detection
- High LFL level alarm and press shutdown
- Loss of deck exhaust flow

No LFL analyzer failures occurred during the data collection period, nor were acceptable %LFL levels exceeded. Based on the review of the system design and operating data, these safety features operated as intended.

1.2.3 Equipment Cost and Energy Savings

The installation of a microprocessor control system enables the plant's existing boiler to be used for VOC destruction. For James River, this approach was the most cost-effective means of addressing federal and state emission standards. As an additional benefit, significant cost savings result from operation of the system because the quantity of collected air was significantly reduced. These savings include:

- Reduction in energy demand for dryer air heating due to reduced air exhaust rates
- Recovery of thermal energy in press exhaust due to use of the exhaust as air for boiler combustion (press exhaust averages 75°F above ambient air temperatues annually).
- Recovery of calorific value of VOCs incinerated in boiler

Table 2 summarizes installed costs for the conversion project at the James River Plant. Annual energy savings are summarized in Table 3.

1.2.4 Application of Microprocessor

A large number of industrial processes can benefit from the microprocessor-based control technology discussed in this report. Economic benefit accrues due to the reduction in process air exhaust volumes which must be processed by a collection system or an incinerator or heated by a process dryer. The techniques used to monitor and control VOC concentrations and to allow lower air volumes are broadly applicable to processes which use heated air in the presence of solvents or other materials. The system reduces plant operating and pollution control costs by reducing fuel required to heat the facility air or the air used in the process.

TABLE 2. CONVERSION COST SUMMARY -- 1985 DOLLARS

Category	Total ($K)
Control System	
1. Microprocessor control system[a]	295
2. LFL Analyzers[b]	145
Subtotal	440
Engineering	
3. Preinstallation analysis and system design	100
Collection and Transport System[c]	
4. Ducting and press modifications	720
5. Boiler modifications	300
Subtotal	1020
Total	1560

[a] Includes computer, pressure transducers, and drives.
[b] Includes two FID analyzers, eight-channel manifold and sample pump.
[c] Items 4 and 5 are unique costs, required only because James River was ducting to a boiler. If the plant had an existing incinerator, then these costs would not be applicable.

TABLE 3. ANNUAL FUEL ENERGY SAVINGS

Units	Air reduction savings	Air preheat savings	Calorific value	Total
MMBtu	34,250	12,670	24,930	71,850
Joules x 10^9	36,127	13,364	26,296	75,787

The application of microprocessor technology studied here is an extension from metal coating (i.e., painting) application. This study proved that the technology is applicable to the paper coating industry and can provide economic benefits through the reduction in energy requirements for a printing process. Although the amount of energy savings and the cost of plant modifications will be different for each application, energy savings, in most cases should offset the capital cost of the plant modifications while ensuring that emission control requirements are satisfied.

A potential user of a microprocessor control system should review the results of this study to assess if similar energy and emission control benefits are possible in other applications of interest. In general, any application where airflows are used to carry away VOCs could be improved through active control of the airflow rates and the VOC concentrations. Depending on the application, the best cleanup approach may be:

- Combustion in a dedicated incinerator
- Combustion in an available plant boiler
- Collection in a VOC recovery facility

The best choice in a given situation will depend on the VOC quantities, airflow rates, plant layout, other plant equipment, energy costs, and permitting requirements.

SECTION 2

COLLECTION AND DESTRUCTION OF VOLATILE ORGANIC COMPOUND EMISSIONS FROM A ROTOGRAVURE PRINTING OPERATION

The microprocessor-based control system which is the subject of this report monitors and controls both airflow rate and vapor concentration level within the ink dryers of a rotogravure printing press. The specific system evaluated is operating at the James River Corporation rotogravure printing facilities in the Kalamazoo, Michigan. This system facilitates incineration of the VOC emissions in an existing plant boiler and also provides energy savings by reducing the amount of dryer and room air that must be heated.

The application of the technology to a paper or fabric coating process represents an extension of the microprocessor concept previously demonstrated by the U.S. Environmental Protection Agency (EPA) and the Department of Energy in paint baking ovens (Reference 1). Paper and fabric coating processes, including printing, operate at lower temperatures so the performance and economic feasibility of the technology is different than previously demonstrated.

The specific features of the James River facility and the VOC control system make this application somewhat unique. However, the general concept, performance levels, and economic parameters demonstrate the potential advantages and capability of the technology for the paper coating industry.

2.1 PROCESS DESCRIPTION

In rotogravure printing, a continuous paper web is passed through multiple gravure printing units, each of which consists of a printing cylinder, an impression cylinder, and an inking system as diagrammed in Figure 1. Ink is applied to the printing cylinder by an ink applicator and the excess is removed by a doctor blade for return to the ink pan. The impression cylinder presses the paper into contact with the ink in tiny cells of the printing surface. For high-speed printing of multiple colors, inks of one color must be dried before application of the next color. Thus, a rotogravure printing press consists of multiple individual press units, each printing one color. Associated with each press printing unit is a partially hooded, heated area through which the paper web passes. Each individual rotogravure unit, including the hood, air heater system, and associated web rollers, is called a deck.

Gravure ink consists of pigment, a resin binder, and solvents. It is fluid and dries entirely by evaporation. Since the gravure process requires fast drying ink, solvents used in the ink must be highly volatile. Typical VOCs from the solvents include low boiling point alcohols, esters, aliphatic

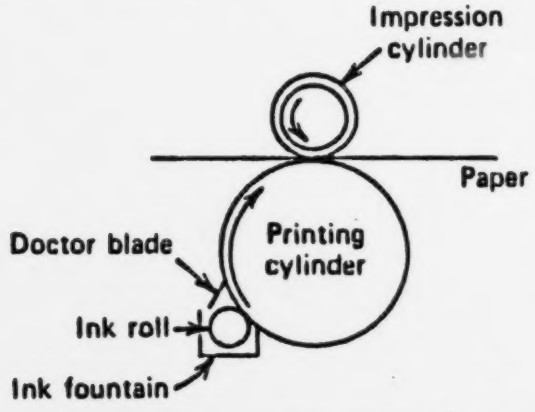

Figure 1. Diagram of a generic gravure printing unit.

and aromatic hydrocarbons, and ketones. Evaporation rate of the solvents varies and depends on the temperature within the dryer. In a typical application without emission controls, the solvent vapors are drawn from the dryer along with large quantities of air and vented to the atmosphere. Sufficient air is required so that the concentration of VOC vapor in the drying hoods is maintained at safe levels to prevent fires or explosions.

2.2 VOC EMISSION CONTROL STRATEGY

Direct venting of the VOCs is a problem because the VOC emissions can react in the atmosphere to form ozone and other undesirable constituents of smog. The James River Corporation has, therefore, installed equipment to collect and destroy the VOC emissions at its Kalamazoo facilities. In selecting a VOC control strategy, James River Corporation evaluated three potential methods of emission control:

- Solvent recovery
- Destruction in a dedicated incinerator
- Destruction in an existing onsite steam boiler

Evaluation of installation and operating costs for these alternatives showed that the use of the existing boiler to incinerate collected deck exhaust was the most appropriate approach.

Incineration in a plant boiler has the following significant benefits:

- Thermal energy in the collected air from the room and deck heaters displaces the need for energy to preheat the combustion air in the plant boiler
- Capital equipment, fuel, and operating costs for a separate incinerator or solvent recovery system are not needed since the incineration occurs through the operation of the existing boiler

- The boiler will operate more reliably than a waste incinerator because it will receive a higher priority in operation and maintenance support than would an incinerator dedicated to emissions cleanup
- The calorific energy content in the emissions of the VOCs is used to meet in part the energy requirements of the James River operations by acting as boiler fuel

James River conducted several tests and evaluated the engineering requirements of ducting the deck exhaust to the existing plant boilers. Ducting, fans, and flow control equipment were designed to meet the simultaneous operating requirements of the boiler and the press decks.

To fit within the combustion air demand of the existing boiler and to minimize duct fan electrical load, the exhaust collection system at James River needed to operate at flowrates which were lower than deck design conditions. The lower flow requirement had the added benefit of reducing the quantity of indoor facility air that must be pulled into the collection system and heated in the press room and the dryers. Reduction of gravure airflow is, however, limited by the need to avoid positive pressure in the dryer hood and the need to maintain a sufficiently low concentration of VOCs in the dryer. The maximum allowable solvent concentration inside the dryer, as set by the National Fire Protection Association (NFPA) standard, is 25 percent of its lower explosive limit unless an appropriate vapor concentration indicator and automatic control are installed to assure safe operation. Lower explosive limit is also termed the lower flammability limit and abbreviated LFL. With appropriate monitoring and controls, the %LFL in the process vapors may approach 50 percent.

At James River, %LFL values exceeding 25 percent are necessary and desirable to operate within the combustion air limit of the existing boiler and to minimize duct fan loads. A microprocessor-based VOC and airflow monitoring and control system was included in the plant modification. The system, which is now operating, monitors deck exhaust airflow rates and, on selected presses, exhaust air %LFL levels. The system automatically controls exhaust fan speeds to minimize airflow rates while maintaining safe VOC concentrations.

SECTION 3

SYSTEM DESCRIPTION

This section describes the effect of microprocessor control on the rotogravure plant press operations and the modifications necessary to implement destruction of VOCs using the plant's existing steam boiler. The emission control system includes the microprocessor-based controller, the VOC collection equipment, the ducting, and the boiler which incinerates the VOCs.

3.1 EFFECT OF AIRFLOW CONTROL ON PRESS OPERATING CONDITIONS

Without an airflow control system, a rotogravure press air system is typically configured as shown in Figure 2. Each deck has an air heater (gas fired or steam heated) and recirculation fan to maintain drying air at the proper temperature. Exhaust fans draw air through the decks and into collection ducts. Air is drawn into the drying hoods from the press room and exhausted to the atmosphere. Table 4 summarizes typical press operating conditions without airflow control for four of the James River presses.

Table 5 shows corresponding design point operating conditions with the airflow control system installed. For Presses 3049 and 3051, exhaust fan speeds are controlled either by a set point flowrate or, if VOC concentrations become too high, by the %LFL analyzer. Presses 3047 and 3052 have only airflow rate control because for these presses James River expects to see safe %LFL levels under all anticipated airflow and press operating

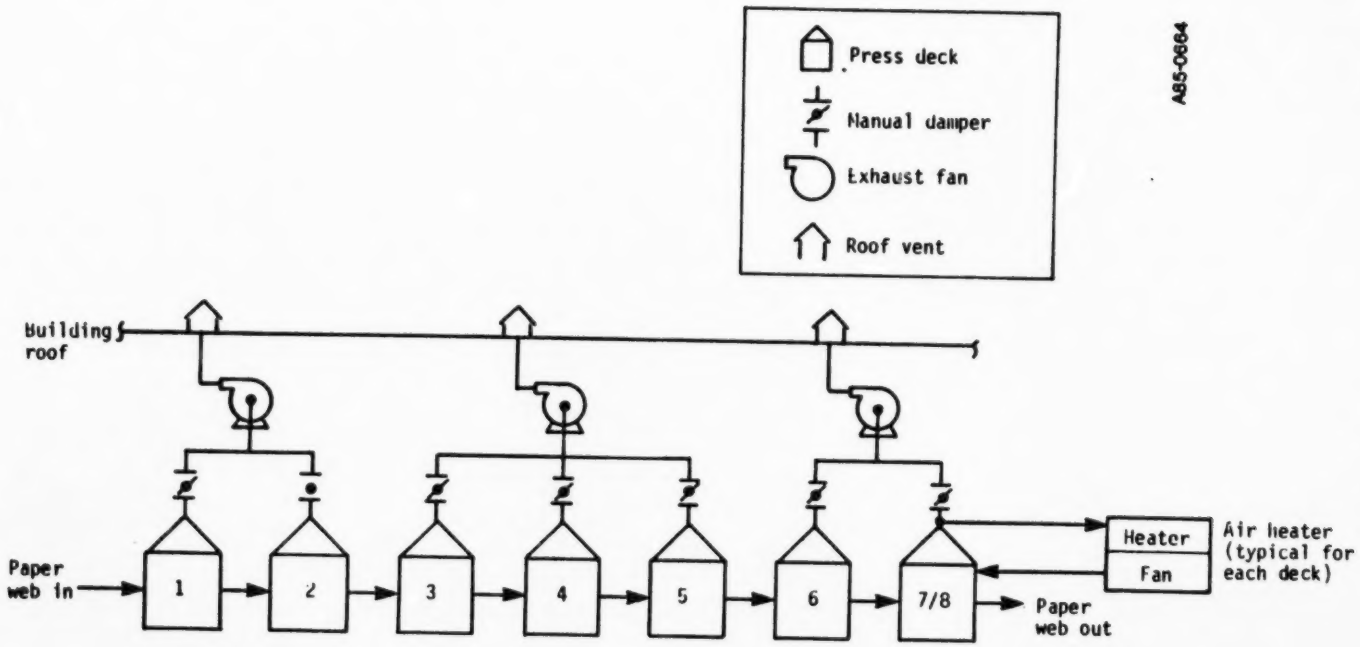

Figure 2. Typical rotogravure press configuration prior to installation of VOC collection system.

TABLE 4. PRESS OPERATING CONDITIONS PRIOR TO CONVERSION

Press number	Total airflow (scfm)	Average %LFL	Average exhaust temperature (°F)	Heat demand (MM Btu/hr)
3047	20,000	3	130	2.0
3049	25,000	2	180	3.8
3051	7,000	15	80	0.2
3052	25,000	5[a]	150	4.1

[a]Estimated

TABLE 5. EXPECTED PRESS OPERATING CONDITIONS WITH MICROPROCESSOR CONTROL

Press number	Total airflow (scfm)	Average %LFL[a]	Average exhaust[a] temperature (°F)	Heat demand (MM Btu/hr)
3047	6,000	9.5	130	0.6
3049	4,000[b]	13.6	149	0.6
3051	4,200[b]	24.6	79	0.13
3052	8,000	20.0	150	1.0

[a]Based on same operating conditions as existed during collection of the survey data shown in Table 4

[b]Minimum flowrate maintained by controller unless %LFL levels exceed acceptable limits

conditions. Comparison of the data in Tables 4 and 5 shows that the total expected airflow with microprocessor control for the four presses is 29 percent of the preconversion flow, with a corresponding decrease in energy required for air heating.

3.2 VOC COLLECTION SYSTEM AT JAMES RIVER

Figure 3 shows the major elements of the VOC control and collection system after conversion of the facility. The major elements are:

- A microprocessor based computer/controller
- A %LFL analyzer
- Variable speed motor drives
- Pressure transducers
- Diversion dampers
- Operator display panel

3.2.1 Computer/Controller

The computer/controller coordinates all aspects of VOC collection system operation. It is a microprocessor-based system which uses a control program stored in nonvolatile memory, along with the control and setpoint constants. The control program is, therefore, retained during power outages and immediately available when power returns. Both digital and analog input/output signals are buffered through signal conditioning and isolation equipment provided with the computer.

3.2.2 LFL Analyzer

%LFL levels in the deck exhausts from Presses 3049 and 3051 are measured by hydrocarbon analyzers which employ the flame ionization detection (FID) method of measuring hydrocarbon concentrations in sampled air volumes. Two analyzer subsystems are provided, one for each monitored press.

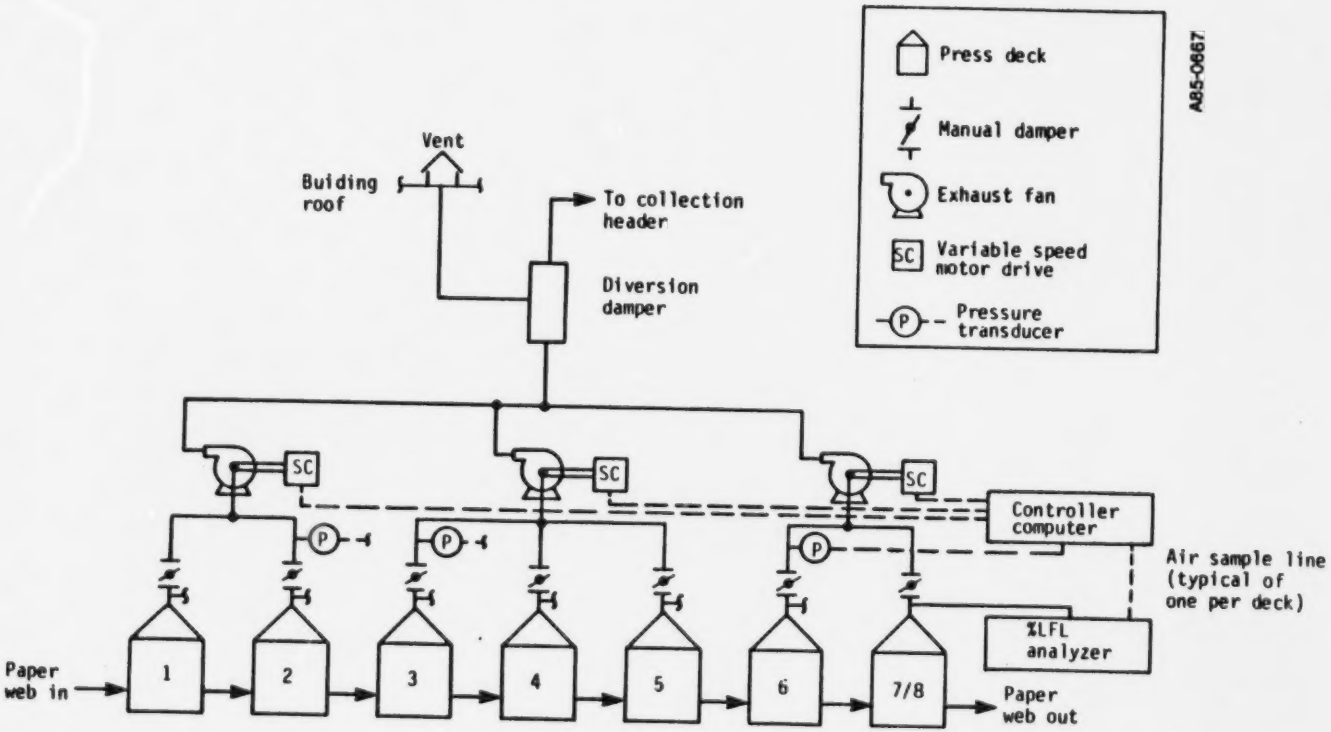

Figure 3. VOC collection schematic.

Air samples from each deck on the monitored presses are brought to the analyzers via stainless steel instrument tubing. Each subsystem contains a single channel analyzer, sample pump, and solenoid valve sample switching manifold. The solenoid valves are controlled by the computer/controller to sequentially switch air samples from each deck into an analyzer. The analyzer sends an analog signal to the computer. The signal is directly proportional to %LFL in the deck.

Each analyzer subsystem is also provided with zero and calibration gas supplies to facilitate periodic calibration by the plant operators.

3.2.3 Variable Speed Motor Drives

Exhaust airflow rates are controlled by adjusting exhaust fan speed. All fans are driven by induction motors which are controlled by solid state, variable frequency, variable speed drives. The computer generates reference control signals for use by the motor drives.

3.2.4 Pressure Transducers

Exhaust airflow rates are measured using sensitive pressure transducers located in the press deck exhaust ducts. Airflow in each duct is proportional to the square root of the differential pressure between the exhaust duct and the press room.

3.2.5 Diversion Dampers

Three-way butterfly valve type diversion dampers, operated by electric motor actuators, are provided in the exhaust collection duct to permit routing of press exhaust to either the collection header or to an exhaust vent. The latter is used primarily during nonprinting periods.

3.2.6 Operator Display Panel

Although the system requires no operator attention or actions during normal press operations, an operator display panel is provided on the press floor. All operating conditions (e.g., airflow rates, fan speeds, damper positions and %LFL) can be monitored from the panel. In addition, control setpoints and other system parameters can be examined and modified from the panel while the system is operating.

3.3 EXHAUST DUCTING AND BOILER SYSTEMS

The VOC exhaust ducting system is configured to feed a portion of the combustion air needed by the James River plant boiler. The boiler operates independent of the ducting system by drawing combustion air from the ducting system with appropriate amounts of fresh air makeup.

Figure 4 shows the component layout of the James River ducting system including the interface with the boiler. These components are sized based on the total collection requirement, flow limitations created by the boiler, and the geographical layout of the printing facility and the boiler. In the system shown, the forced draft fan must be running for the exhaust transport fan to operate. Unless the transport fan is operating, the warmup and purge isolation damper is tightly closed, and exhaust is vented to the atmosphere. Upon boiler startup, the isolation damper remains closed while the transport fan draws purge air into the process chamber and pushes it on to the boiler system. When steady flow conditions are achieved, the isolation damper is opened, and vent dampers are closed. A negative pressure (-0.1 in. of H_2O) is maintained in the process chamber by a variable speed drive on the transport fan. The transport fan is controlled by the boiler control system.

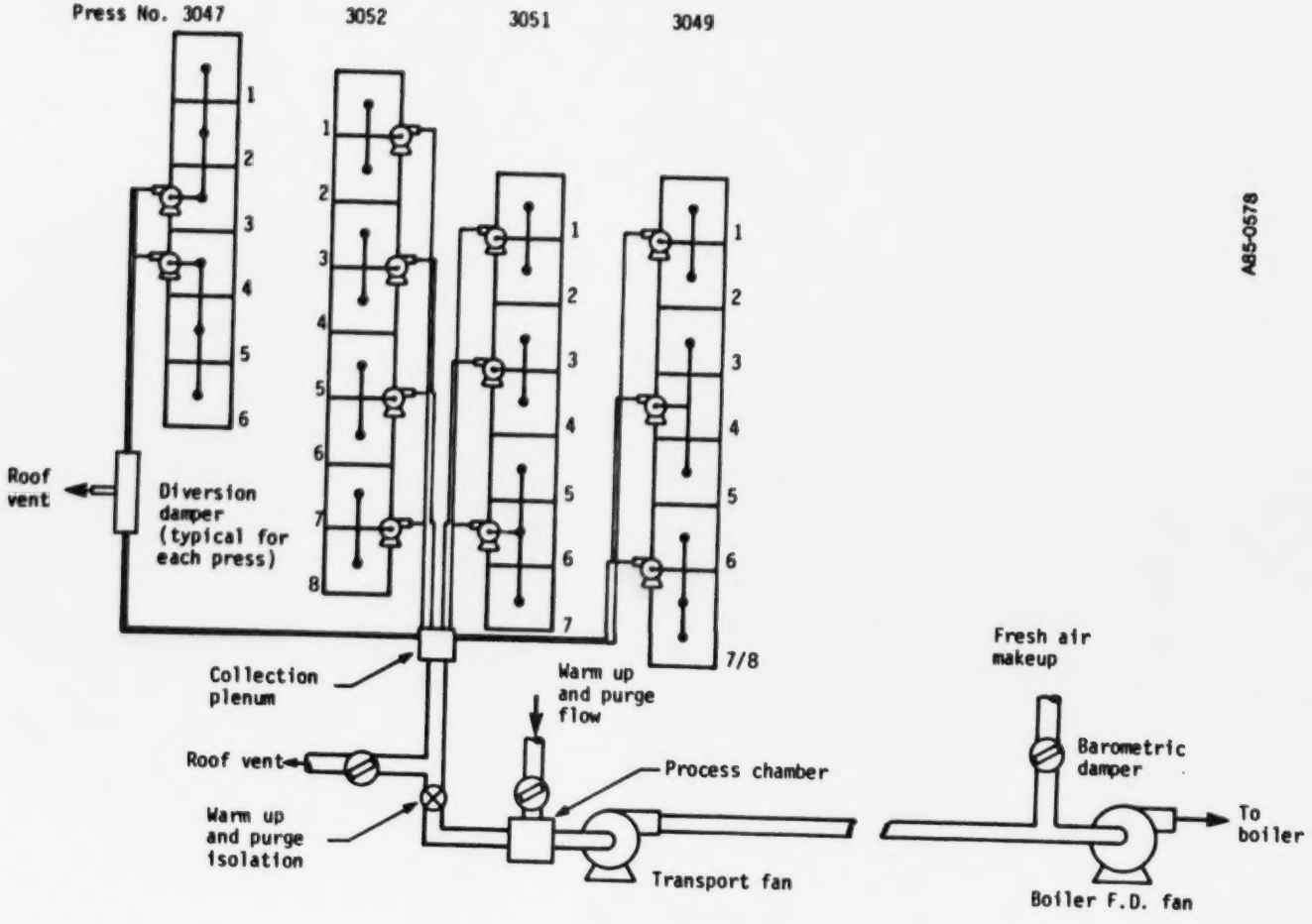

Figure 4. Typical press room exhaust ducting system.

3.4 OTHER PLANT MODIFICATIONS

Several other modifications and subsystems were necessary to implement VOC destruction using the existing plant boiler:

- Air ductwork was installed between the transfer fan and the boiler forced draft fan
- A new forced draft fan was installed because bearings on the existing fan could be damaged at the anticipated concentration of VOCs in the press exhaust
- Modifications were necessary to some press decks in order to provide better sealing, thereby allowing operation at reduced fan speeds

3.5 VOC CONTROL SYSTEM OPERATION

3.5.1 Normal Operation

Under normal operation, the computer monitors exhaust duct pressure data and adjusts the fan speeds to maintain desired airflow rates. For Presses 3049 and 3051, which have full LFL control, the speed of the appropriate fan is increased if the %LFL exceeds the setpoint (currently 30 percent). This results in increased airflow, which dilutes the VOC concentration and lowers the %LFL. Fan speed is increased until the %LFL is reduced to the setpoint.

3.5.2 Abnormal Operation

If the controller detects %LFL above 40 percent, an alarm is sounded and the fan on the affected deck is set to maximum speed. If the %LFL exceeds 50 percent, the press is automatically shutdown until the problem is corrected. Operation of the %LFL analyzer is also monitored to ensure that analyzer data is accurate by introducing a hydrocarbon reference gas to calibrate the instrument.

3.5.3 Press Startup

The controller monitors press operating status and automatically sets the fan speed to a maximum during press startup to avoid transient buildup of VOC concentration. After a preset time interval, the controller reduces fan speed to reach the airflow or %LFL setpoint level.

SECTION 4

DATA COLLECTION

Process parameters are monitored by permanent instrumentation installed as a part of the VOC control system. However, the existing system has no provisions for data storage. Therefore, process parameters needed for this report were recorded during the test period by a temporary data acquisition system. The system consisted of a data interface unit and a personal computer. A floppy disk and thermal printer were also provided for hard-copy data output and storage. Figure 5 is a block diagram showing the temporary data acquisition system. Existing sensor signals were hard wired into the data acquisition unit. The unit was located in the basement of the press building adjacent to the VOC control computer console. All connections were made on the field (sensor) side of the control computer input/output isolation devices.

Table 6 lists the available data signals from the microprocessor system which were monitored.

The personal computer was programmed to automatically scan all data parameters once every two minutes. Data were converted to engineering units and further processed as required. Data were averaged (e.g., fan speed) or integrated (e.g., vapor quantity) over time and were periodically output to the printer and disk for permanent storage. Data were normally stored once

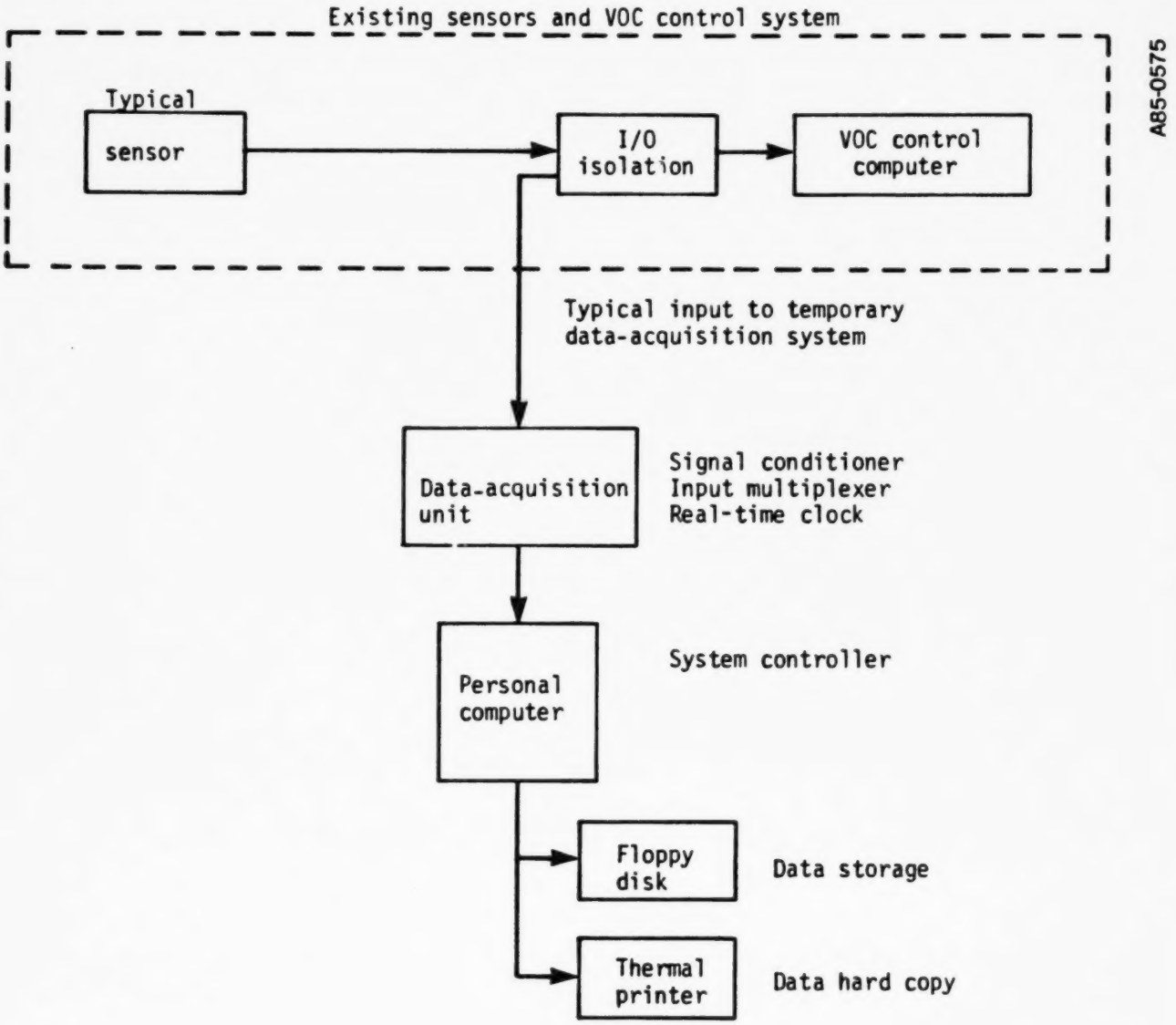

Figure 5. Data acquisition system block diagram.

TABLE 6. DATA ACQUISITION PARAMETERS

Press number	Signal	Parameter	Signal range	Parameter range
3047	PI471	Air pressure (flow) decks 1, 2, 3	0 to -10 VDC	0 to -1.4 in.
3047	PI472	Air pressure (flow) decks 4, 5, 6	0 to -10 VDC	0 to -1.4 in.
3047	SC471	Exhaust fan speed decks 1, 2, 3	4 to 20 ma	100 to 50 percent
3047	SC472	Exhaust fan speed decks 4, 5, 6	4 to 20 ma	100 to 50 percent
3047	SI47	Press running	off to on	0 to 110 VAC
3049	PI491	Air pressure (flow) decks 1, 2	0 to -10 VDC	0 to -3.5 in.
3049	PI492	Air pressure (flow) decks 3, 4, 5	0 to -10 VDC	0 to -3.5 in.
3049	PI493	Air pressure (flow) decks 6, 7, 8	0 to -10 VDC	0 to -3.5 in.
3049	SC491	Exhaust fan speed decks 1, 2	4 to 20 ma	100 to 50 percent
3049	SC492	Exhaust fan speed decks 3, 4, 5	4 to 20 ma	100 to 50 percent
3049	SC493	Exhaust fan speed decks 6, 7, 8	4 to 20 ma	100 to 50 percent
3049	AI49	Percent LFL	0 to 10 VDC	0 to 100 percent
3049	SOV491	LFL sample select from deck 1	off to on	0 to 110 VAC
3049	SOV492	LFL sample select from deck 2	off to on	0 to 110 VAC
3049	SOV493	LFL sample select from deck 3	off to on	0 to 110 VAC
3049	SOV494	LFL sample select from deck 4	off to on	0 to 110 VAC
3049	SOV495	LFL sample select from deck 5	off to on	0 to 110 VAC
3049	SOV496	LFL sample select from deck 6	off to on	0 to 110 VAC
3049	SOV497	LFL sample select from deck 7	on to off	0 to 110 VAC
3049	SOV498	LFL sample select from deck 8	off to on	0 to 110 VAC
3049	SI49	Press running	off to on	0 to 110 VAC
3051	PI511	Air pressure (flow) decks 1, 2	0 to -10 VDC	0 to -2.2 in.
3051	PI512	Air pressure (flow) decks 3, 4	0 to -10 VDC	0 to -2.2 in.
3051	PI513	Air pressure (flow) decks 5, 6, 7	0 to -10 VDC	0 to -2.2 in.
3051	SC511	Exhaust fan speed decks 1, 2	4 to 20 ma	100 to 50 percent
3051	SC512	Exhaust fan speed decks 3, 4	4 to 20 ma	100 to 50 percent
3051	SC513	Exhaust fan speed decks 5, 6, 7	4 to 20 ma	100 to 50 percent
3051	AI51	Percent LFL	0 to 10 VDC	0 to 100 percent
3051	SOV511	LFL sample select from deck 1	off to on	0 to 110 VAC
3051	SOV512	LFL sample select from deck 2	off to on	0 to 110 VAC
3051	SOV513	LFL sample select from deck 3	off to on	0 to 110 VAC
3051	SOV514	LFL sample select from deck 4	off to on	0 to 110 VAC
3051	SOV515	LFL sample select from deck 5	off to on	0 to 110 VAC
3051	SOV516	LFL sample select from deck 6	off to on	0 to 110 VAC
3051	SOV517	LFL sample select from deck 7	on to off	0 to 110 VAC
3051	SOV518	LFL sample select from deck 8	off to on	0 to 110 VAC
3051	SI51	Press running	off to on	0 to 110 VAC
3052	PI501	Air pressure (flow) decks 1, 2	0 to -10 VDC	
3052	PI502	Air pressure (flow) decks 3, 4	0 to -10 VDC	
3052	PI503	Air pressure (flow) decks 5, 6	0 to -10 VDC	
3052	PI504	Air pressure (flow) decks 7, 8	0 to -10 VDC	
3052	SC501	Exhaust fan speed decks 1, 2	4 to 20 ma	100 to 50 percent
3052	SC502	Exhaust fan speed decks 3, 4	4 to 20 ma	100 to 50 percent
3052	SC503	Exhaust fan speed decks 5, 6	4 to 20 ma	100 to 50 percent
3052	SC504	Exhaust fan speed decks 7, 8	4 to 20 ma	100 to 50 percent
3052	SI50	Press running	off to on	0 to 110 VAC

every 10 min. A faster storage rate (2 min) mode was provided for use during collection of transient data.

After completion of the test period, all temporary equipment and wiring were completely removed.

Data collection was conducted during the week of September 23, 1985. All four presses underwent periods of normal operation, make-ready and down-time during this effort. Sufficient data were collected to fully characterize the performance of the system over a wide range of operating conditions.

SECTION 5

PERFORMANCE EVALUATION

The objective of the data acquisition efforts at the James River Corporation printing operation was to evaluate the feasibility of microprocessor use for efficient VOC control in a paper coating operation. The onsite data provide the basis to:

- Document exhaust flowrates and %LFL over a range of gravure operating conditions
- Determine the effect of exhaust flow control on VOC collection
- Evaluate energy savings over a production run sequence and estimate the savings over a typical yearly production schedule

Data taken at James River meet these objectives.

5.1 SYSTEM PERFORMANCE SUMMARY

As shown in Table 7, the VOC control system appears to operate as expected. Measured airflow rates are very close to the expected values, which represent a 71 percent decrease in airflow when compared to the preconversion values. Measured values of %LFL are considerably below the expected values primarily because the measurements were taken for a press run where the product ink coverage was less than maximum. Expected concentrations are not directly comparable to measured values because the expected %LFL values were calculated assuming maximum ink coverage and complete VOC collection. Similarly, the differences between measured and

TABLE 7. VOC COLLECTION SYSTEM DATA SUMMARY

	Prior to conversion			After Conversion					
				Expected			Measured		
Press number	Exhaust flowrate (scfm)	Exhaust temperature (°F)	%LFL	Exhaust flowrate (scfm)	Exhaust temperature (°F)	%LFL	Exhaust flowrate (scfm)	Exhaust temperature (°F)	%LFL
3047	20,000	130	2.9	6,000	130	9.5	6,105	NM[a]	NM
3049	25,000	175	2.2	4,000	149	13.6	3,839	72	6.1
3051	7,000	79	15.3	4,200	79	24.6	4,245	103	8.2
3052	25,000	150	4.7	8,000	150	20.0	7,900	NM	NM
	77,000	134	6.3	22,200	127	16.9	22,089	90[b]	7.2

[a]Not measured.
[b]Average temperature of total exhaust airflow as measured in main collection header.

expected exhaust temperature are not significant since dryer temperatures are adjusted by the operaters to meet the needs of the particular product being printed.

5.2 PERFORMANCE DATA

Figure 6 shows the fan speed reference signal from the controller versus time for deck 1 of Press 3047, and Figure 7 shows the airflow rate versus time for the same deck. Time is shown relative to a 24 hour clock. The controller changes fan speed either (1) to maintain constant airflow under changing exhaust header conditions such as would occur if other press exhaust fans are starting or stopping or (2) to change the airflow rate based on changing %LFL or airflow demand. As shown in Figures 6 and 7, the airflow rate and fan speed remain relatively constant at the 1000 scfm setpoint during the 1600 hours to 0800 hours press run. At 0800 hours, the press was shutdown, and the fan motors were turned off by the operators. As described in Section 3.1, Press 3047 did not have an LFL monitor. Therefore, no %LFL data were obtained for this press.

Fan speed and %LFL data for Press 3049 are shown in Figure 8. %LFL remained relatively constant during steady state press operation and returned to near zero, as expected, when the press was shutdown. %LFL during this period averaged about 12 percent and never exceeded 18 percent. For this deck, the ink coverage ratio was about 80 percent. Even with this relatively high coverage, the setpoint %LFL of 30 percent was never approached. Figure 9 shows the exhaust flowrate for the deck during this period. The exhaust flowrate was stable at the setpoint of 500 scfm. This setpoint value was selected based on the operating condition survey in which James River identified the minimum flowrate needed to avoid deck blowout. With each deck

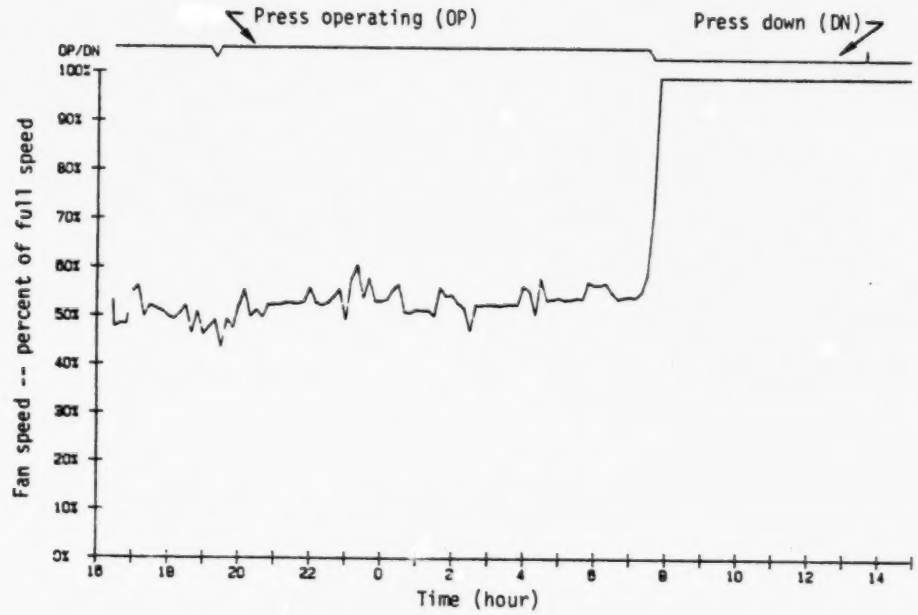

Figure 6. Press 3047 fan speed versus time.

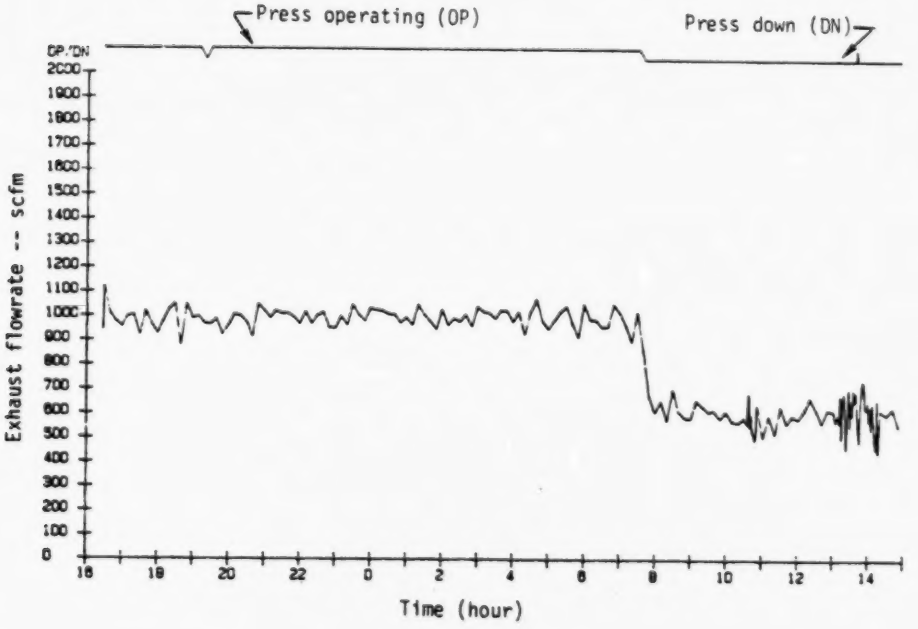

Figure 7. Press 3047 exhaust airflow versus time.

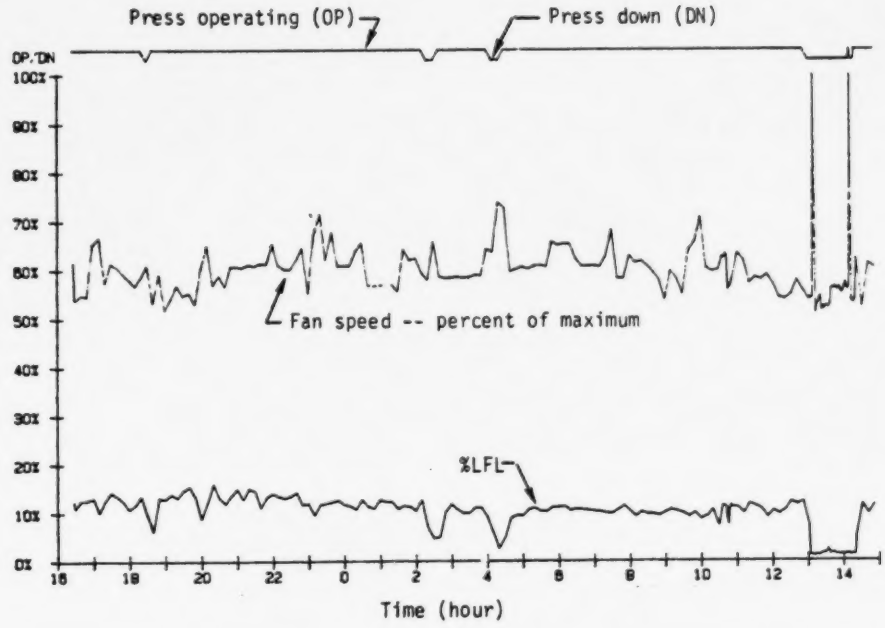

Figure 8. Press 3049 fan speed and %LFL versus time.

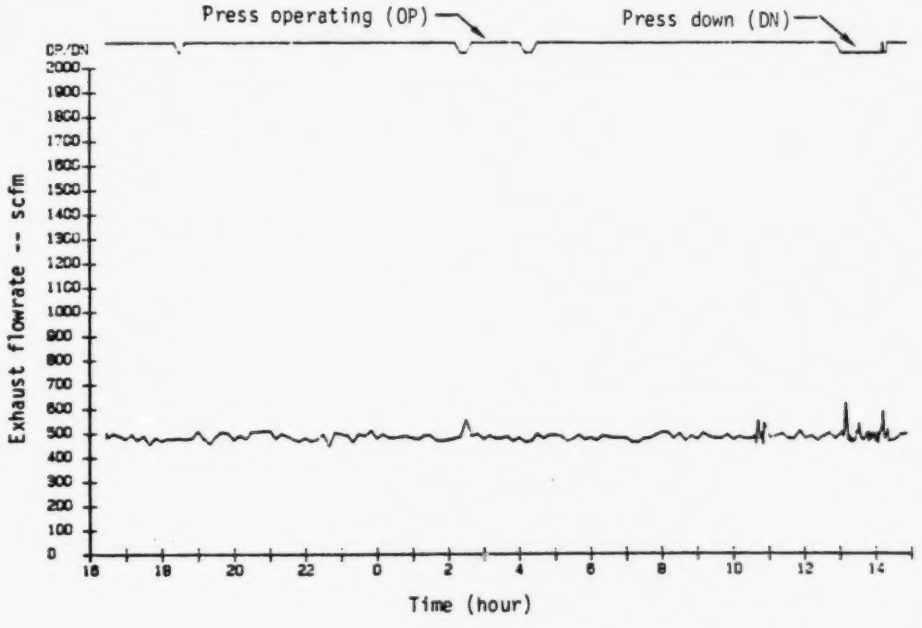

Figure 9. Press 3049 exhaust airflow versus time.

operating at 500 scfm, the press exhaust flow is 4000 scfm as indicated in Table 7. These data illustrate that fan speed and exhaust flow reductions are achieved without generating unacceptable %LFL levels.

Fan speed and %LFL levels for Press 3051 are shown in Figure 10, and exhaust flowrates are shown in Figure 11. The press was undergoing startup for a new run during the data acquisition period and experienced numerous starts and stops. The large variations in fan speed and flowrate occur because the controller momentarily increases fan speed for the press startup. During steady state press operation, the flowrates and %LFL levels approach stable values. Peak %LFL value for this press condition was 19 percent.

Figures 12 and 13 show the flowrate and fan speed operating data for Press 3052. The controller held the flowrate near the 1000 scfm setpoint throughout the run. No %LFL data were obtained for this press because, as described in Section 3.1, this press did not have any LFL monitor.

5.3 DESTRUCTION EFFICIENCY

Collected VOCs are routed to an existing, onsite boiler and are injected into the boiler as a component of the combustion air. Destruction efficiency of the VOCs within the boiler (incinerator) can be estimated from the operating temperature of the combustion chamber and the dwell time of the compounds at this temperature. Dwell times of 0.4 to 0.8 seconds and operating temperature of 1450°F are adequate to provide at least a 96 percent destruction efficiency (Reference 2). According to boiler design data provided by James River, the James River boiler, which can be fired by either natural gas or oil, provides combustion temperature in excess of 2000°F and dwell times of about 2 seconds. Based on these values, destruction

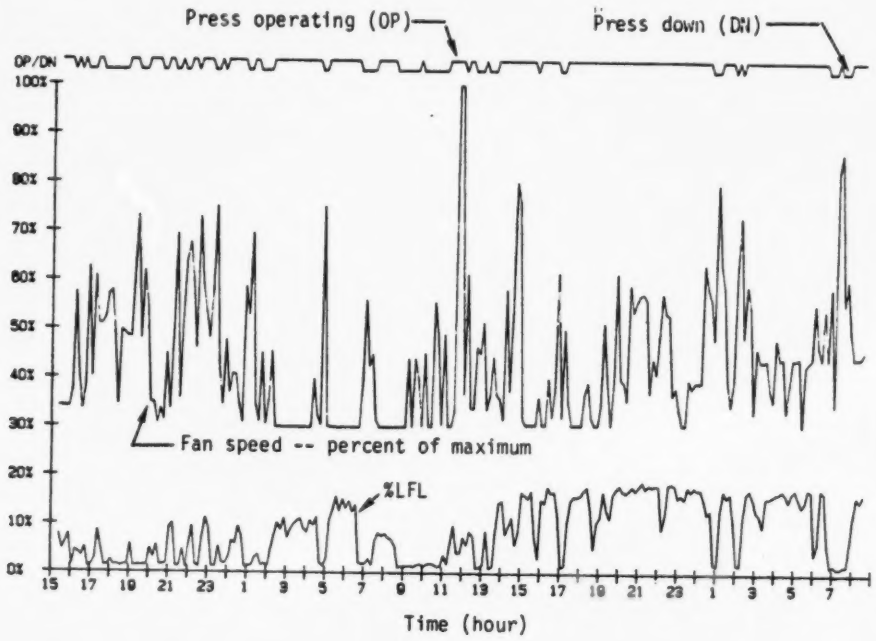

Figure 10. Press 3051 fan speed and %LFL versus time.

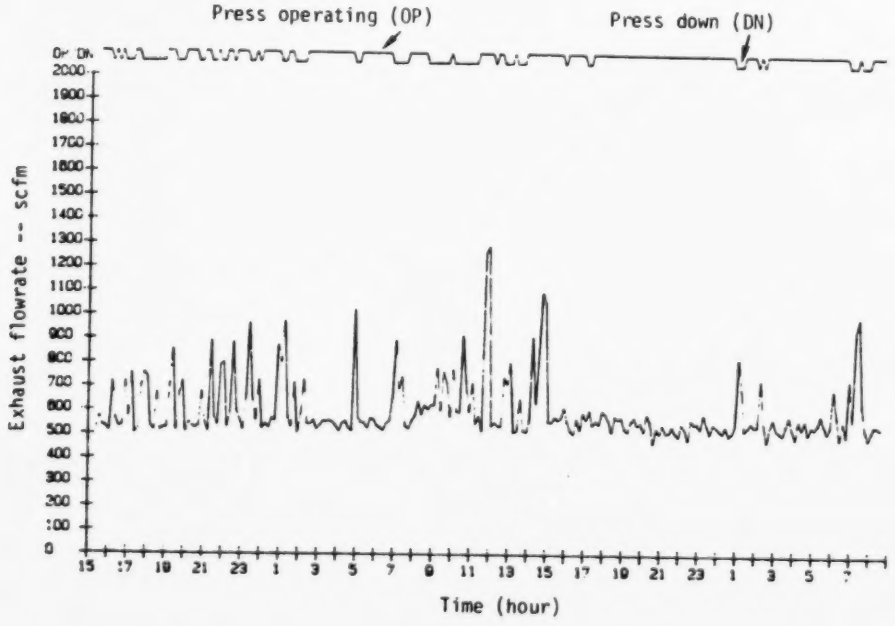

Figure 11. Press 3051 exhaust airflow versus time.

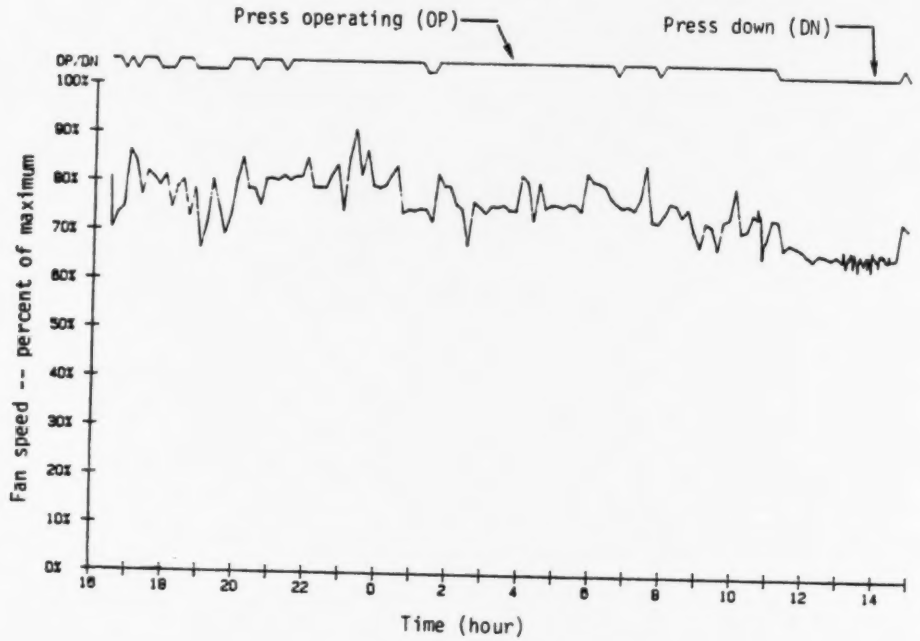

Figure 12. Press 3052 fan speed versus time.

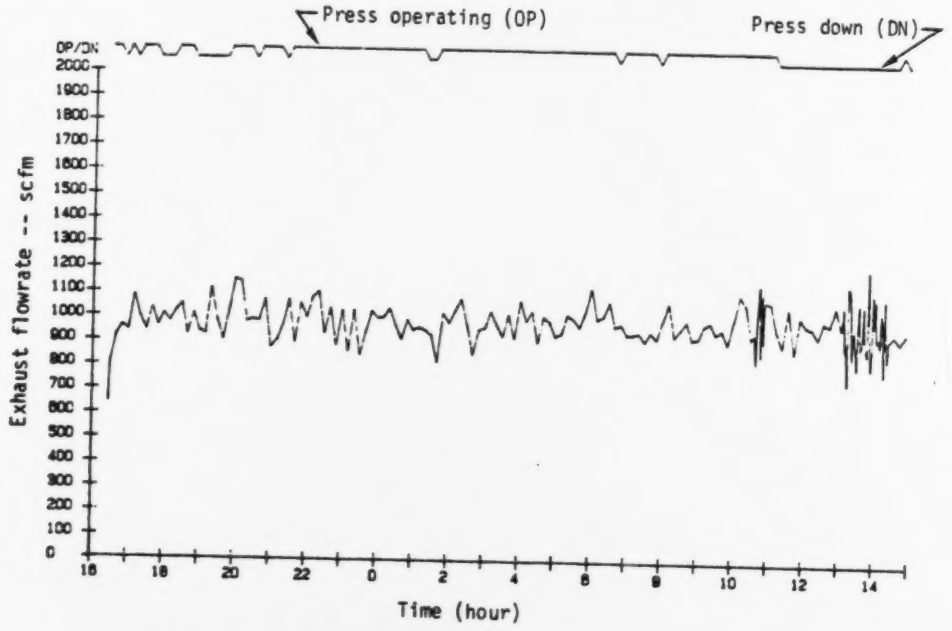

Figure 13. Press 3052 exhaust airflow versus time.

efficiency is estimated to be greater than 96 percent, although no measurements were taken to verify this destruction efficiency.

5.4 SAFETY

The control system incorporates several safety features and interlocks, including:

- LFL analyzer failure (flameout) detection
- High LFL level alarm and press shutdown
- Loss of deck exhaust flow

The loss of airflow safety interlock was inadvertently actuated on Press 3049 while data were being taken for this evaluation. At the time, data were being collected to correlate fan speed with %LFL level by manually adjusting the fan speed. When the fan speed was reduced to 35 percent of maximum, the pressure in the deck became positive with respect to the press room, resulting in blowout of deck air into the room. This was caused by the back pressure of the other exhaust fans operating into the common exhaust header. The condition was immediately detected by the controller, which initiated a press shutdown. After determining the cause of the shutdown, the affected exhaust fan was returned to automatic speed control, and the press was restarted without further incident. Other than a momentary press shutdown, this incident had no adverse effect on the press, the control system, the VOC collection system, or the plant boiler. Indeed, the shutdown showed that the control system and safety interlock logic were operating correctly.

SECTION 6

EQUIPMENT COST AND ENERGY SAVINGS

This installation of a microprocessor control system enabled James River to use the plants existing boiler for VOC destruction. For James River, this approach was the most cost-effective means of addressing federal and state emission standards. As an additional benefit, significant energy savings result from operation of the system. These include:

- Reduction in energy demand for dryer air heating due to reduced air exhaust rates
- Recovery of thermal energy in press deck exhaust due to use of the exhaust as air for boiler combustion (deck exhaust averages 75°F above ambient temperature annually)
- Recovery of calorific value of VOCs incinerated in the boiler

Installed costs and energy savings are discussed below.

6.1 INSTALLED COSTS

Equipment and installation costs for the conversion are summarized in Table 8. Categories 1 and 2 in the table identify cost specifically related to installation of the microprocessor based control system, including two %LFL analyzers. Categories 3, 4, and 5 represent the costs necessary to collect and route the press exhaust air to the existing James River boiler

TABLE 8. CONVERSION COST SUMMARY -- 1985 DOLLARS

Category	Equipment cost ($K)	Installation cost ($K)	Total ($K)
Control System			
1. Microprocessor control system	240	55	295
-- Microcomputer system -- Pressure transducers -- Variable speed drives			
2. LFL Analyzers	130	15	145
-- Single channel FID analyzer -- 8 channel sample manifold -- Sample pump			
Subtotal	370	70	440
Engineering			
3. Preinstallation site survey	--	100	100
-- Measurement of operating conditions -- System design			
Collection and Transport System			
4. Ducting and press modifications	540	180	720
5. Boiler modifications	200	100	300
Subtotal	740	280	1020
Total	1110	450	1560

and to utilize the boiler for VOC destruction. Cost categories 3, 4, and 5 are unique to the James River application.

6.2 ANNUAL FUEL SAVINGS

6.2.1 Value of Press Exhaust Air Reduction

Although the specific press operating conditions and schedule would not be released by James River, the total annual exhaust flow is expected to be reduced by approximately 22×10^9 scf due to microprocessor operation if James River continues with their typical operating schedule. For an annual average outside temperature of 50°F and an average drying temperature of 125°F, the dryer air must be heated an average of 75°F. For a boiler efficiency of 88 percent, the annual Btu savings is as follows:

$$\text{Btu savings} = 22 \times 10^9 \text{ scf} \times 0.076 \text{ lb/scf} \times 0.24 \text{ Btu/lb°F} \times 75°F \div 0.88$$
$$= 34{,}250 \text{ MMBtu per year}$$

6.2.2 Value of Preheated Boiler Combustion Air

Annual fuel savings resulting from the use of the heated press exhaust air for boiler combustion can be calculated in a similar manner using the following:

- Annual press exhaust volume = 8.2×10^9 scf
- Temperature rise = 75°F
- Boiler efficiency = 88 percent

$$\text{Btu savings} = 8.2 \times 10^9 \text{ scf} \times 0.076 \text{ lb/scf} \times 0.24 \text{ Btu/lb°F} \times 75°F \div 0.88$$
$$= 12{,}670 \text{ MMBtu per year}$$

6.2.3 VOC Calorific Value

The heating value of VOCs in the exhaust air is approximately 40 Btu/lb of exhaust air. Therefore,

Btu savings = 40 Btu/lb x 8.2 x 10^9 scf x 0.076 lb/scf

= 24,930 MMBtu per year

SECTION 7

APPLICATION SUMMARY

A large number of industrial processes can benefit from the microprocessor-based control technology discussed in this report. Economic benefit accrues from the application of this technology due to the reduction in exhaust volumes which must be processed by a collection system or an incinerator. The techniques used to monitor and control VOC concentrations (%LFL) and to allow lower air volumes are broadly applicable to processes which use heated air in the presence of solvents or other materials. The system reduces plant operating and pollution control costs by reducing fuel required to heat air used by a process.

The cost and performance data presented in Section 6 show that annual fuel savings, based on reduced air volumes only and not considering the value of energy recovered in the incinerator, can be large. Individual users can assess their fuel cost savings knowing their cost of fuel. Furthermore, use of a microprocessor control system can significantly reduce the capital costs of complying with emission requirements because the controls will significantly reduce the capacity requirements of the collection equipment.

The technology can, therefore, be considered by organizations which face present or future emissions reduction requirements, as well as by organizations interested in reducing total operating costs.

Preliminary feasibility evaluations, conducted by organizations with potential applications for this technology, would consider:

- Capital costs for equipment installation and plant modifications
- Annual operating and maintenance costs
- Annual energy savings

7.1 CAPITAL COSTS

Installed costs for implementation of microprocessor-based airflow control systems are strongly affected by application and site-specific factors. Table 8 gives useful estimates of control system costs. Items 1 and 2 in the table are basically generic to the technology. Items 3, 4, and 5 will depend on the existing facility configuration, knowledge of the process, and experience of the engineering contractor.

Costs for modifications to existing process equipment should be estimated by assessing the requirements for:

- Changes needed to implement air volume control (e.g., variable speed motors or variable dampers)
- Changes to existing ductwork
- Changes to ovens or other equipment necessary to permit operation at lower airflow rates (i.e., lower negative pressures)

Costs for modifications needed for VOC destruction are also very application and site specific. Preliminary evaluations should identify and consider:

- Existing facilities (e.g., boilers) which could be used for VOC incineration
- Uses for heat from a dedicated incinerator, if no suitable existing incinerator is available

- Costs to collect and transport VOC ladden air to the incinerator location
- Costs for features to ensure safe operation under steady and transient flow conditions and other ducting modifications.

7.2 OPERATING AND MAINTENANCE COSTS

Previous experience indicates that operating and maintenance (O&M) costs are relatively low. The systems are normally configured for totally automatic operation during both steady-state and transient process operating conditions.

Operating costs for additional equipment, such as exhaust air transfer fans, should be identified along with additional fuel costs for dedicated VOC incinerators, if included.

Normal maintenance requirements include:

- Weekly calibration of LFL analyzers, requiring about one manhour per week
- Annual inspection and calibration of sensors and control elements, requiring about 40 manhours per year

Other maintenance requirements are similar to those for other industrial control equipment of this type.

7.3 ANNUAL ENERGY SAVINGS

Annual energy savings should be estimated using calculations of the type presented in Section 6.1. To estimate fuel savings achievable through reductions in exhaust air volume, it is necessary to estimate the levels of reduction possible while maintaining safe operation. This is very dependent on both the process equipment design and the operating conditions of the specific application.

In general, equipment manufacturers are very conservative when designing exhaust air systems and often provide oversized fans which result in very low VOC concentrations during operation. This is done for safety, without considering energy costs for heating the large volumes of air. Therefore, it is often possible to achieve significant reductions in exhaust air volumes through proper monitoring and control of the purge airflow rates, while maintaining safe operating conditions.

If %LFL values are known for a process, one might evaluate the cost savings by analyzing a process assuming that flowrate is reduced to the point where %LFL is 50 percent. If %LFL is not known a reasonable estimate might be to assume a 50 percent reduction in exhaust air volume. If preliminary results based on one of these assumptions appear promising, more detailed evaluations can be conducted based on actual operating data.

7.4 SITE SURVEY

If preliminary evaluations appear promising, a site survey should be conducted to quantify actual process operating conditions, including exhaust air volumes, air temperatures, and %LFL levels. These data would then be used to support the evaluation of specific control system equipment requirements, process equipment modifications, and operating conditions after the conversion. Detailed economic evaluations could then be made using these data to determine if implementation is justified.

7.5 SUMMARY

In summary, this effort provided an evaluation, detached from the viewpoints of the EPA, the user, and the equipment supplier, of an advance technology method of reducing VOC emissions through microprocessor control of a previously uncontrolled operation.

The application of microprocessor technology studied here is an extension from a metal coating (i.e., painting) application. This study proved that the technology is applicable to the paper coating industry and can provide economic benefits through the reduction in energy requirements for a printing process. Although the amount of energy savings and the cost of plant modifications will be different for each application, energy cost savings can be achieved, while ensuring that emission control requirements are satisfied.

A potential user of a microprocessor control system should review the results of this study to assess if similar energy and emission control benefits are possible in other applications of interest. In general, any application where airflows are used to carry away VOCs could be improved through active control of the airflow rates and the VOC concentrations. Depending on the application, the best cleanup approach may be:

- Combustion in a dedicated incinerator
- Combustion in an available plant boiler
- Collection in a VOC recovery facility

The best choice in a given situation will depend on the VOC quantities, airflow rates, plant layout, other plant equipment, energy costs, and permitting requirements.

REFERENCES

1. Charles H. Darvin, et al., "Environmental and Energy Benefits of Microprocessor Control of Oven Air Flows from a Coil Coating Operation: A Case Study," by the Chemical Coaters Association, EPA-600/2-84-179. Dec. 1984, PB 85-121 135.

2. Factory Mutual Engineering Corporation, Loss Prevention Data, Fume Incinerators, November 1975.

METRIC CONVERSION TABLE

To Convert From	To	Multiply by
Btu/lb °F	watt hr/Kg °C	0.3588
ft^3	m^3	28.137×10^{-3}
ft^3/min (scfm)	m^3/sec	0.4689×10^{-3}
ft^3/min (scfm)	l/sec	0.4689
in of H_2O	Pa	0.3345×10^{-3}
lb	Kg	0.4536
MMBtu	Joules	1.0548×10^9
MMBtu/hr	Watts	0.2931×10^6
°F	°C	a

a °C = (°F - 32)/1.8